Title: Skyscrapers

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Issue Date: Jan-1932

Publisher: Ohio State University, College of Engineering

Citation: Ohio State Engineer, vol. 15, no. 3 (January, 1932), 4-6, 19.

URI: http://hdl.handle.net/1811/34862

Appears in Collections: Ohio State Engineer: Volume 15, no. 3 (January, 1932)

A. I. U. BUILDING

The Empire State Building

Skyscrapers

By

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THE skyscraper is distinctively an engineering development in American architecture. It is the result of the invention of cheap methods of rolling and manufacturing structural steel, coupled with the introduction of the idea of making the structural frame a self-supporting unit upon which is hung the walls and the floors, instead of making the walls heavy enough to support the floors.

The first skyscraper was erected in Chicago in 1885 and was 10 stories high. There are now more than five thousand buildings in the United States that are higher than this 10-story building of 45 years ago. Within the period of only six years following its erection, the maximum height had more than doubled. The Masonic Temple in Chicago, erected in 1891, reached the unprecedented height of 21 stories. This held the record until the St. Paul building, 26 stories high, was built in New York in 1896, followed by the 30-story Park Row Building in 1898.

New York had now definitely taken the lead away from Chicago and has held it consistently. In 1913 the 58-story Woolworth Building, 792 feet high, was completed and held its supremacy for 16 years. Within the past two years New York has produced a number of extremely high buildings, notably the Bank of Manhattan and the Chrysler building, both of which overtop the old Woolworth; and then last spring the Empire State Building, 1250 feet high, was finished. This is the tallest structure ever built by man, but will probably not retain that title long.

There are no insurmountable engineering difficulties in the construction of a building twice the height of the Empire State Building. In fact, it is rumored that a 2000-ft. tower is now being planned in Chicago, but it is doubtful if the returns on such a structure would show a profit on the investment, unless a considerable figure were charged to advertising.

In fact, the question of economics is inseparably tied up with any project of this magnitude. A study of this subject was made by engineers and economists employed by a large New York investment company, and it was shown that, provided other similar buildings were not constructed within half a mile, a building 75 stories high, in the region of Forty-second Street and Fifth Avenue, would show a reasonable return on the investment. Buildings in that vicinity which are less than 20 stories high do not show a reasonable profit because of the extremely high land values.

There are many problems connected with the construction and use of these excessively tall buildings which were not present in the lowlier structures. Elevator service is one which has been solved in part, by successfully operating two cars in the same elevator shaft at the same time, and by so perfecting the elevator operation that speeds as high as 1000 ft. per minute may be attained without discomfort to the passengers.

And that brings us to another point which was unthought of a few years ago. That is the comfortable habitability of the upper stories of these very tall structures. Deflections and vibrations may occur which may become noticeable to sensitive persons; and, of course, any noticeable movement of the floor under their feet when they are conscious that they are a thousand feet above the ground causes apprehension in nervous people.

The pressure of the wind on a structure will cause it to deflect; and the fact that the wind is not constant will make this deflection variable from moment to moment, causing vibration or sway. Call to mind the movement of the top of a tree in a moderate wind. This, to a very exaggerated degree, represents the action of a tall building in a wind storm.

The writer has been interested in the deflections and stresses in tall building frames for a long time. Twenty years ago he supervised the taking of such measurements on a 16-story building, which at that time was regarded as fairly high. The movements of this building were so small as to be detected only by the use of very delicate instruments and were of interest only as a means of determining the distribution of stresses in the frame. But within the past ten years, the question of vibration has attained prominence due to the construction of a number of comparatively slender buildings, in which the vibration during windstorms has been noticeable to the occupants of the upper floors. The question then is no longer, alone, that of providing strength enough for safety, but also of providing sufficient rigidity to prevent noticeable vibrations. When the American Insurance Union Building in Columbus was built, especial attention was given to the wind bracing, so that a very rigid structure resulted. Measurements of the amplitude and time of vibration of this building have been made in a large number of windstorms, and the results are extremely gratifying from the standpoint of the occupants, because the movements are too small to be detected even by the most timid. But from the standpoint of the investigator, the building is too rigid to yield satisfactory experimental data.

The most easily measured factor is the period, or time of vibration, of the structure. This is a definite characteristic of a given building and is almost independent of the velocity of the wind, just as the time of swing of a pendulum is constant, regardless of its amplitude. The distance that the top of the building moves under the action of a wind depends upon the height and stiffness of the structure.

The time of vibration of the A. I. U. Building, that is, the time it requires to complete a cycle from an extreme deflection in one direction back to that same deflection, is a trifle over two seconds. That is, there are about 26 complete vibrations per minute; and in a 35-mile wind, the movement of the top of the tower is less than one-fourth of an inch. This would mean that if we were to experience a wind velocity of 100 miles per hour, the movement of the top of the tower might reach two inches, which again would scarcely be noticeable, because of the comparatively slow time of a complete cycle, a little over two seconds.

It is reported that in one of the extremely slender buildings in New York City, a stenographer became seasick as a result of the sway of the building in a windstorm. Her illness was probably due to several causes, among which the actual movement of the structure may have been the least. Seasickness, as you know, has several contributing causes. Among these are the condition of one's stomach at the time and the rhythmic movement of objects before the eyes.

If lighting fixtures are suspended by chains or flexible cords from the ceiling, and if the natural time of swing of the fixture as a pendulum happens to nearly correspond to some multiple of the time of vibration of the building, the fixture will pick up the motion and in a short time its swing may become several inches in amplitude or perhaps a foot or more.

The synchronous swaying of these fixtures overhead coupled with the noise of the storm and the howling of the wind through leaky window weather strips, probably have more to do with the discomfort and nervousness of the occupants than the actual movements of the structure.

In a dark interior closet on the 37th floor of the A. I. U. Building, there are 12 pendulums of varying lengths. Some of these pendulums are never quiet, due to their picking up and magnifying the vibrations caused by the elevator machinery which is located near by.

In a 38-mile wind, the 46-inch pendulum has been observed to swing as much as 7¾ inches. At this time the actual movement of the thirty-seventh floor was less than one-tenth inch, but the time of the 46-inch pendulum corresponds almost exactly to the time of vibration of the building, and this small movement was picked up and magnified by the pendulum.

The amount and time of vibration of a large number of buildings in New York City have been determined by the use of an instrument similar to a seismograph, which is an instrument used in measuring earthquake disturbances. Elaborate provisions have been made in the new Empire State Building, for studying wind pressures and their effects, but as yet no results are available. In this building it is proposed to measure the actual pressure of the wind on the structure at a large number of points and also to measure its deflections and time of vibration. Such investigations necessarily involve a great deal of time, because windstorms of sufficient intensity to give reliable data do not occur frequently and also such investigations require the uninterrupted use of an elevator shaft and certain other spaces in the building which are not usually available except at night.

When the height of a building does not exceed 20 or 30 stories and the width of its base is more than one-fifth of its height, the question of vibration, even in the severest storms, is not important. So, in the great majority of structures, strength is the main consideration in the design of the wind bracing. The building, of course, must be safe in the severest hurricane which is probable in its locality, and most of the buildings in our cities are conservatively

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designed and would suffer little damage in such a storm.

We have very positive evidence regarding this point in the records of the hurricane which passed over Miami, Florida, in 1926. The actual velocity of the wind in this storm is not known, because the anemometer was blown away. Its last record showed 128 miles per hour. Two steel-framed buildings which had been constructed during the Florida boom without competent engineering advice were so severely damaged that one of them stood 24 inches out of plumb after the storm, and both were ordered taken down by the city building department. The *Miami Daily News* Building, which stands in a neighboring block with an equally severe exposure and a greater height, but which was properly designed according to modern standards, suffered no damage.

And so we may conclude that our present engineering knowledge and skill are competent for the construction of buildings higher than any yet built, which will be both safe and comfortable. And the probabilities are that higher buildings will be built, although there is little justification for them, either from an architectural or an economic standpoint.